



Direct Interaction of Deoxyribonucleic Acid with the Quantum Vacuum that May Lead to Cumulative Damages with Time

Meis C*

National Institute for Nuclear Science and Technology, CEA – Centre d'Etudes de Saclay, France

***Corresponding author:** Constantin Meis, National Institute for Nuclear Science and Technology, CEA, Centre d'Etudes de Saclay, 91191 Gif-sur-Yvette, France, Email: constantin.meis@cea.fr

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Abstract

The aim of this study is to make a detailed and comparative topological analysis of the single photons and the Deoxyribonucleic Acid (DNA) geometrical structures in order to deduce possible interaction mechanisms, particularly with the quantum vacuum fluctuations. As revealed by the experimental evidence and advanced quantum electrodynamics calculations the quantum vacuum is a sea of transient photons of all wavelengths whose fluctuations interact with matter. Single photon topology and structure is quite characteristic and can be represented by a three dimensional helicoid configuration of the vector potential amplitude over a wavelength. The geometrical configurations of the A DNA, B DNA and Z DNA macromolecules are also known precisely and appear to be similar to that of the photon. Using experimental data and recent quantum electrodynamics theoretical results we put in evidence for the first time that the right-hand canonical B DNA has exactly an identical geometrical configuration with right-hand circular polarization photons having a wavelength equal to the B DNA pitch per turn of helix. Conversely, we show that the radial amplitudes of the right-hand A DNA and the left-hand Z DNA are slightly bigger and smaller respectively compared to photon trains having wavelengths equivalent to the corresponding pitch per helix distances. The amplitudes of the photons electric and magnetic fields are also calculated and revealed to be considerably high locally. We conclude that the DNA alterations by homothetic photons in the soft X-rays range, especially those due to the quantum vacuum fluctuations, may be quite significant contributing to the DNA damage accumulation with time and are worthy to be extensively studied.

Keywords: DNA topology; Single photon structure; Electromagnetic vacuum fluctuations; Photons; DNA homothetic interaction

Introduction

A synthesis of the experimental results, as well as advanced quantum electrodynamics calculations, have shown that single photons are wave-corpuscles extended over a wavelength along the propagation axis [1-6], having a local radial extension of the order of a quarter of the wavelength [7-9] and guided by a non-local vector potential wave function. The photon quantized vector potential amplitude moves helicoidally over a period with circular (right or left) polarization perpendicular to the propagation axis [4-6,10-

12]. In addition, it has been shown that the electromagnetic vacuum, a cosmic field permeating all of space, is composed of fluctuating transient photons of all modes and polarizations [13-15]. Obviously, the helicoid configuration of the electromagnetic field is analogue to that of the DNA macromolecules. Hence, a direct interaction between the DNA and photons with equivalent wavelengths ranged in the soft X-rays spectrum will inevitably provoke strong structural and chemical modifications with physiological consequences. Furthermore, even in absence of any external radiation, the DNA macromolecules are immersed

in the electromagnetic vacuum entailing a permanent coupling with transient homothetic vacuum photons with unknown consequences in the DNA physiology and stability. Consequently, it is of high importance to investigate explicitly the topological configurations and the electric and magnetic fields amplitudes of the homothetic photons within the DNA macromolecules. In what follows, we make a detailed and comparative analysis of this particular physical aspect and we evaluate the electric and magnetic fields strengths of the homothetic photons aligned along the nitrogen bases ACGT (adenine, cytosine, guanine, and thymine) that may lead to alterations with time.

Photons and the Electromagnetic Quantum Vacuum

We recall briefly the single photon geometrical representation. In quantum electrodynamics theory, photons are considered as point particles described by an associated wave [4-6,16-18]. The point particle concept of the photon is an efficient mathematical tool permitting to describe states before and after interaction with the quantized energy levels of atoms and molecules. In reality, the experimental evidence has shown that the photon is not a point particle and that it is impossible to conceive a single k -mode photon within a length less than the wavelength [1-5]. Consequently, it is impossible to detect precisely a photon at a given coordinate of the propagation axis while the experiments have shown that the detection probability has a physical sense only within a volume equivalent to the cube of the wavelength [2,4,5]. This entails that the photon radial expansion is roughly shorter than the wavelength, which indeed has been confirmed experimentally [8-10]. A synthesis of the experimental facts [5,10,15] yields that a single k -mode photon is a quantum of the electromagnetic field, a *wave-corpucle* extended over the wavelength λ_k along the propagation axis. It has a lateral extension η_k shorter than the wavelength, with the quantized vector potential amplitude α_{0k} oscillating over a period at the angular frequency ω_k with circular (right or left) polarization. The whole *wave-corpucle* packet carries the energy $E_k = \hbar\omega_k$,

where $\hbar = h/2\pi$ is Planck's reduced constant, and has a momentum $\vec{p}_k = \hbar\vec{k}$ while it propagates guided by a non-local vector potential wave function.

$$\vec{\alpha}_{k\lambda}(\vec{r}, t) = \alpha_{0k} \left(\hat{\varepsilon}_{k\lambda} e^{i(\vec{k}\cdot\vec{r} - \omega_k t + \theta)} + \hat{\varepsilon}_{k\lambda}^* e^{-i(\vec{k}\cdot\vec{r} - \omega_k t + \theta)} \right) \quad (1)$$

where $|\vec{k}| = \omega_k / c$ is the wave-vector, c the speed of

light in vacuum and λ takes only two values corresponding to left or right circular polarization expressed by the complex unit vector $\hat{\varepsilon}_{k\lambda}$.

The vector potential amplitude α_{0k} for a single free of cavity k -mode photon with angular frequency ω_k writes [6,15,19-21].

$$\alpha_{0k} = \xi \omega_k \quad \text{with} \quad |\xi| = \left| \frac{\hbar}{4\pi e c} \right| = 1.747 \cdot 10^{-25} \text{ Volt m}^{-1} \text{ s}^2 \quad (2)$$

where e is the electron-positron charge.

Hence, the vector potential of a free single photon in the plane wave representation writes

$$\vec{\alpha}_{k\lambda}(\vec{r}, t) = \xi \omega_k \left(\hat{\varepsilon}_{k\lambda} e^{i(\vec{k}\cdot\vec{r} - \omega_k t + \theta)} + \hat{\varepsilon}_{k\lambda}^* e^{-i(\vec{k}\cdot\vec{r} - \omega_k t + \theta)} \right) = \omega_k \vec{\Xi}_{k\lambda}(\vec{r}, t) \quad (3)$$

Various experiments have demonstrated that the radial spatial extension of a k -mode photon is approximately $\eta_k \approx 0.25 \lambda_k$ [7-9] while a theoretical analysis [6,15,22]

yields the value

$$\eta_k = \sqrt{8a} \lambda_k \approx 0.242 \lambda_k \quad (4)$$

with $a = 1/137$ the fine structure constant.

Considering a circular polarization the summation of the electromagnetic field energy density over a wavelength yields the energy of a single photon $\hbar\omega_k$ [6,15]. Thus, the photon vector potential follows a precession with circular polarization over a wavelength λ_k and extends laterally over a radius of the order η_k describing a periodic helicoid curve along the propagation axis. It generates locally an electric and magnetic field, $\vec{\varepsilon}_k$ and $\vec{\beta}_k$ respectively, which are perpendicular to each other ($\vec{\varepsilon}_k \perp \vec{\beta}_k$) and orthogonal to the propagation axis ($\vec{\varepsilon}_k \cdot \vec{k} = \vec{\beta}_k \cdot \vec{k} = 0$). Their amplitudes are proportional to the square of the angular frequency [6,12,15].

$$|\vec{\varepsilon}_k| = |-\partial \vec{\alpha}_{k\lambda}(\vec{r}, t) / \partial t| = \xi \omega_k^2 ;$$

$$|\vec{\beta}_k| = |\vec{\nabla} \times \vec{\alpha}_{k\lambda}(\vec{r}, t)| = \xi \omega_k^2 / c \quad (5)$$

The zero-frequency level corresponds to zero energy electromagnetic field. At that level, the vector potential is also zero but the fundamental field $\vec{\Xi}_{k\lambda}$ in equation (3) does

not vanish and reduces to

$$\vec{\Xi}_{0\lambda} = \xi \left(\hat{\varepsilon}_{\lambda} e^{i\phi} + \hat{\varepsilon}_{\lambda}^* e^{-i\phi} \right) \quad (6)$$

$\vec{\Xi}_{0\lambda}$ is the *Electromagnetic Field Ground State*, a real field permeating all of space ($\omega_k \rightarrow 0 \Rightarrow \lambda_k \rightarrow \infty$) having zero-

energy, zero vector potential as well as zero electric and magnetic fields (dark light). Under this condition, the field $\vec{\Xi}_{0\lambda}$ is a real vacuum component, the *electromagnetic quantum vacuum*, having electric potential dimension. Obviously, photons are oscillations of the electromagnetic quantum vacuum [6,13-15,20,21]. Furthermore, the electromagnetic field ground state may have a complex structure yet to be discovered [5,10,15,23].

Heisenberg's energy-time uncertainty relation applied to equation (5) entails directly that the vector potential amplitude is also subject to a fluctuation uncertainty

$$\delta E_k \cdot \delta t \approx \hbar \quad \Rightarrow \quad \delta \alpha_{0k} \cdot \delta t \approx \xi \quad (7)$$

Consequently, fluctuations of the *quantum electromagnetic vacuum* may generate transient states of photons of any wavelength at any point in space.

Topological Analogy between DNA and Photons. DNA Interaction with Homothetic Photons

The DNA structure is well known and widely commented in the literature [24-26]. This nucleic acid is composed of nucleotides molecules each containing a phosphate group, a 5-carbon sugar called deoxyribose and a nitrogen base. The molecules are distributed over a double helix geometrical configuration with the nitrogen bases ACGT aligned along the helix diameter.

We denote by λ_{DNA} , the periodic distance of the helix strands corresponding to "DNA wavelength", and by δ_{DNA} the thickness of the strands borders composed of deoxyribose and phosphate groups. The diameter of the helix is ρ_{DNA} while η_{DNA} is the mean radius corresponding to the distance from the helix axis to the middle of the border molecules, that is

$$\eta_{DNA} = (\rho_{DNA} - \delta_{DNA}) / 2 \quad (8)$$

The measured values for the geometric characteristics of both right-hand A and B DNA [27,28] as well as of the left-hand Z DNA [29,30] are given in Table 1 and they are compared to those of photons with equivalent wavelengths. The corresponding photon frequencies $\nu_k = \omega_k / 2\pi$, laying in the range extreme-UV to soft-X rays, as well as the photon electric and magnetic field amplitudes (rounded to the nearest integer) are also given.

It appears that the topological structure of the DNA is similar to a train of photons with equal wavelengths $\lambda_k = \lambda_{DNA}$ and identical polarization, right-hand for the A

DNA and B DNA and left-hand for the Z DNA. It is worth noting (in bold on Table 1) the surprising coincidence for the canonical B DNA which has exactly the same geometrical

configuration and radial extension ($\eta_{B DNA} = \eta_k$) with a right-hand polarization photon having the same wavelength ($\lambda_{B DNA} = \lambda_k$) entailing a perfect homothetic physical

structure. For the left-hand Z DNA a symmetrical left-hand photon train with same wavelength covers totally the macromolecule. Conversely, the A DNA has a lateral extension significantly larger than that of an equal wavelength photon.

	λ_{DNA}	η_{DNA}	ρ_{DNA}	δ_{DNA}	λ_k	η_k	ν_k (PHz)	ε_k (V nm ⁻¹)	β_k (T)
A DNA	2.82	1.17	2.6	0.256	2.82	0.68	106.3	78	260
B DNA	3.38	0.83	2.0	0.338	3.38	0.82	88.7	54	181
Z DNA	4.56	0.71	1.8	0.380	4.56	1.10	65.7	30	99

¹All length values are in nm

Table 1: DNA geometric values compared to k-mode photons with equivalent wavelengths.

The homothetic photons electric and magnetic fields are aligned on the helix axis along the nitrogen bases ACGT and can directly induce various effects, particularly for the B DNA, such as bonds break up, dissociation-recombination process, chemical reactions, ionizations,...etc. Even if the coupling occurs during short time intervals the high amplitudes of the

electric and magnetic field strengths, given in Table 1, could be sufficient to produce permanent structural and chemical modifications with physiological consequences.

In fact, vacuum fluctuations occur permanently and everywhere in space at all wavelengths and in all directions.

DNA macromolecules have also a random distribution in space in all directions. Consequently, even in absence of real photons the DNA is immersed permanently in the *electromagnetic quantum vacuum* and due to its photon-like geometry it may interact directly with fluctuating transient vacuum photons. The vacuum transient photons have naturally intrinsic circular polarization, they do not have time to propagate and act locally as electric and magnetic perturbations. Hence, over long time intervals, the superposed effects of successive random events entail that the possibility for direct alteration of the B-DNA due to vacuum fluctuations photons with similar wavelength might not be negligible.

Conclusions

We have shown that the topological configurations of the A, B and Z DNA are similar to photons with equivalent wavelengths and polarizations. There is an intriguing perfect homothetic coincidence with exactly the same lateral extension between the canonical B DNA and a circular right-hand polarized photon with wavelength $\lambda_k = 3.38 \text{ nm}$. Hence, there is a direct coupling between homothetic photons and the B DNA macromolecules. The photons electric and magnetic fields, whose values are extremely high locally, are aligned exactly along the nitrogen bases ACGT on the helix axis and may lead to considerable alterations. Hence, transient photons from the quantum vacuum fluctuations having identical wavelengths and polarizations with the DNA macromolecules may act locally upon the ACGT bases as permanent random electromagnetic perturbations. Consequently, these effects are worthy to be investigated extensively because they may have direct consequences by inducing damage accumulation with time influencing the DNA evolution.

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